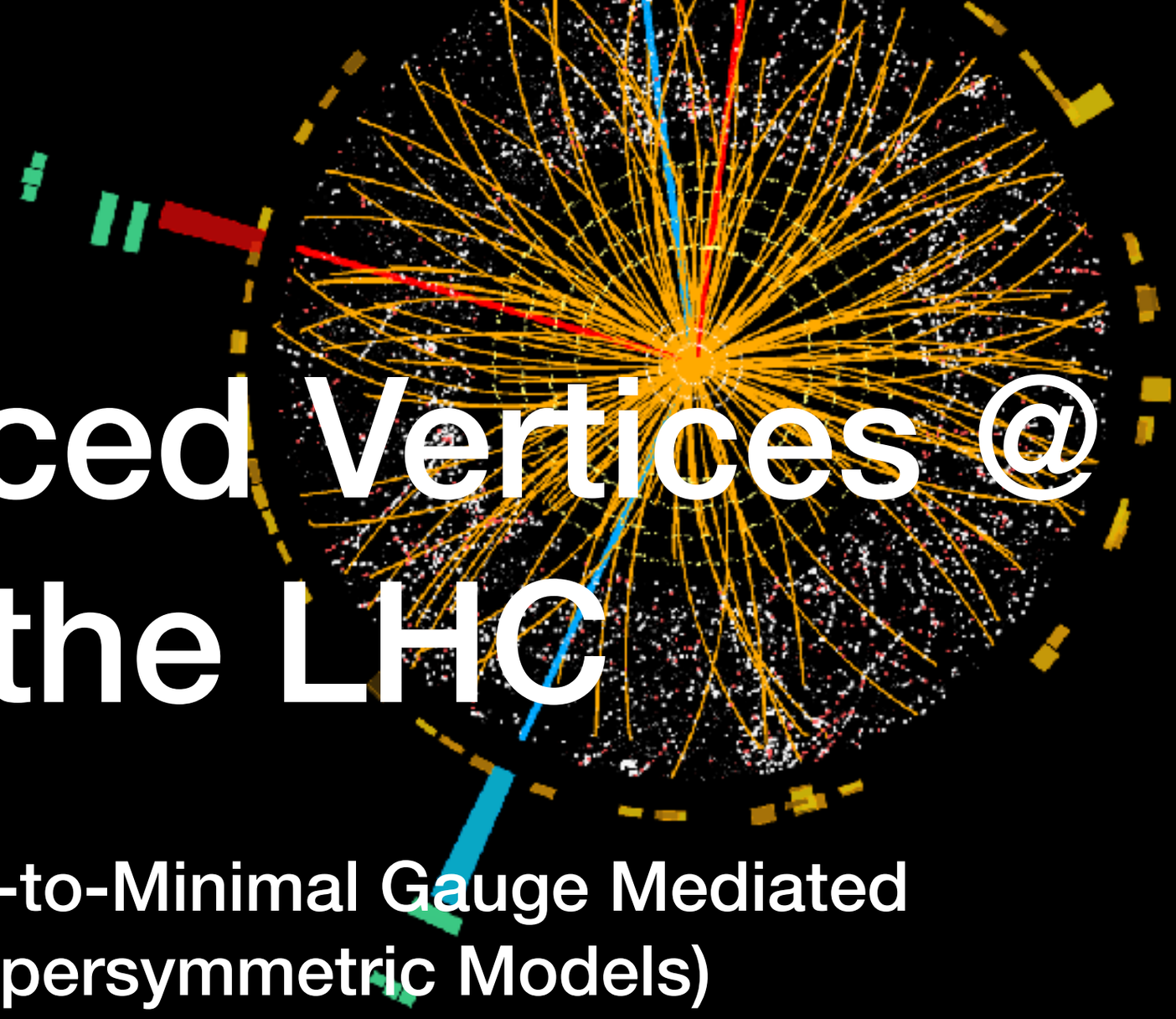


Displaced Vertices @ the LHC

(for Next-to-Minimal Gauge Mediated Supersymmetric Models)

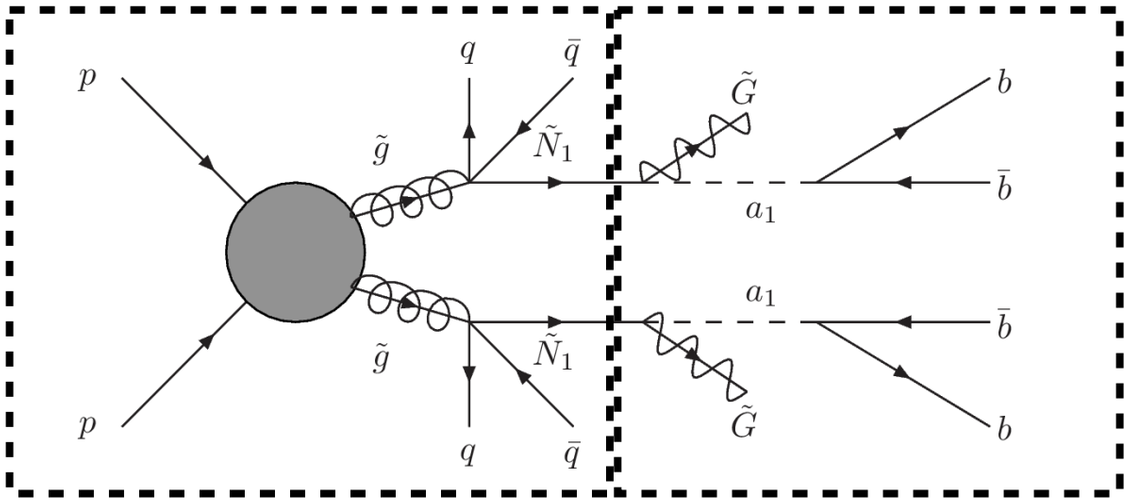
Based on EPJC (2016) 76:482 & ongoing work

Nishita Desai; LUPM, Montpellier

Collaborators: B. Allanach, M. Badziak, G. Cottin, C. Hugonie, R. Ziegler

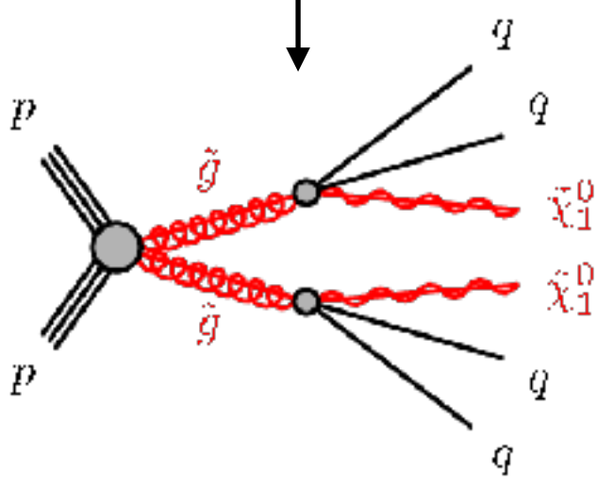
6 March 2018; Montpellier

NMSSM: Long Lived Neutral Particles



Same as standard SUSY

New decay

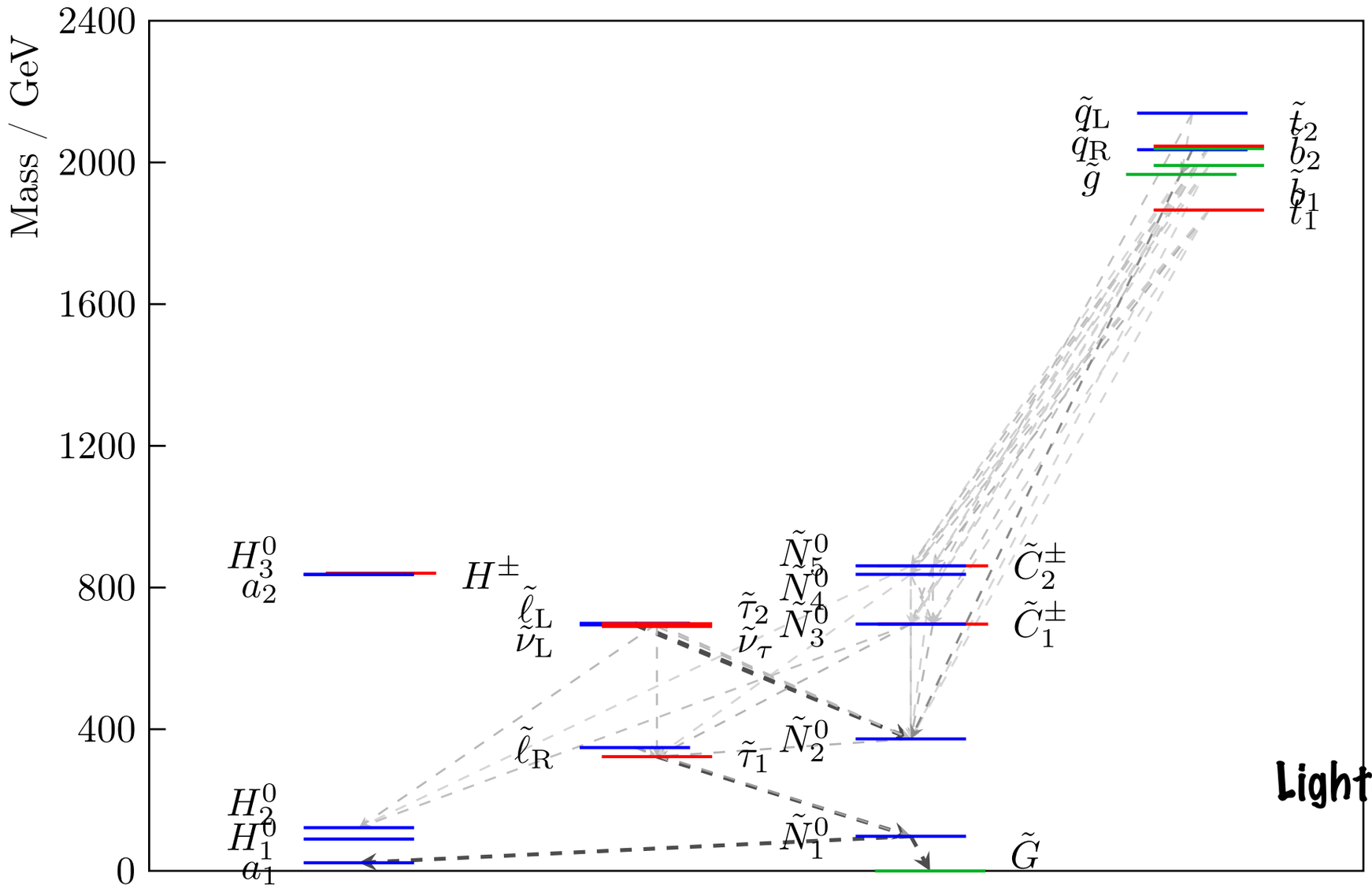


- Supersymmetry with extra singlino & gauge mediation
  - ✓ Predicts 125 GeV higgs mass
  - ✓ Doesn't violate low-scale observables
  - ✓ Predicts high masses of strongly charged SUSY partners
- Predicts a pseudo-scalar boson of mass ~ 30 GeV; all chains end in producing this boson
- This boson has a lifetime ~ 1 mm (due to boost, decays after traveling ~100 mm in the detector)

Questions:

1. **Can ordinary SUSY searches find this scenario?**
2. **What are the effects of the extra pseudo scalar**

Spectrum of model



$m_{H_1^0}$	$m_{H_2^0}$	m_{a_1}	$m_{\tilde{N}_1}$	$m_{\tilde{N}_2}$	$m_{\tilde{e}_1}$	$m_{\tilde{\tau}_1}$	$m_{\tilde{g}}$	$m_{\tilde{u}_R}$	$m_{\tilde{b}_1}$	$m_{\tilde{t}_1}$	$m_{\tilde{G}}$
90	122.1	23	97.6	373	348	323	1966	2045	1992	1866	5×10^{-8}

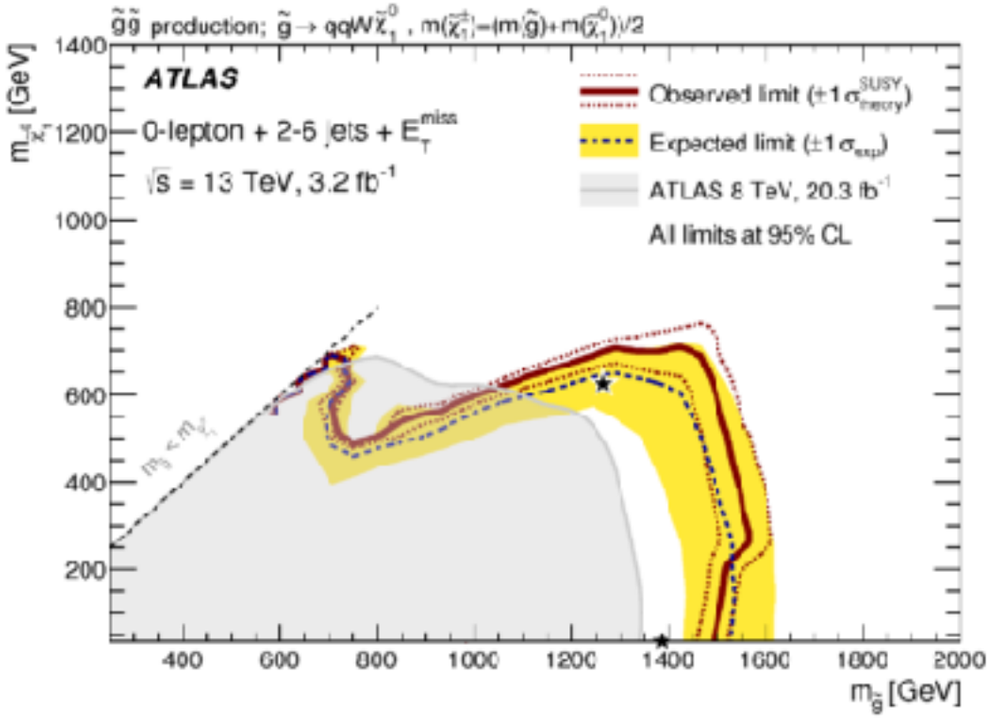
Naturally predicts heavy strong sector to get the right higgs mass

Lightest neutralino not stable

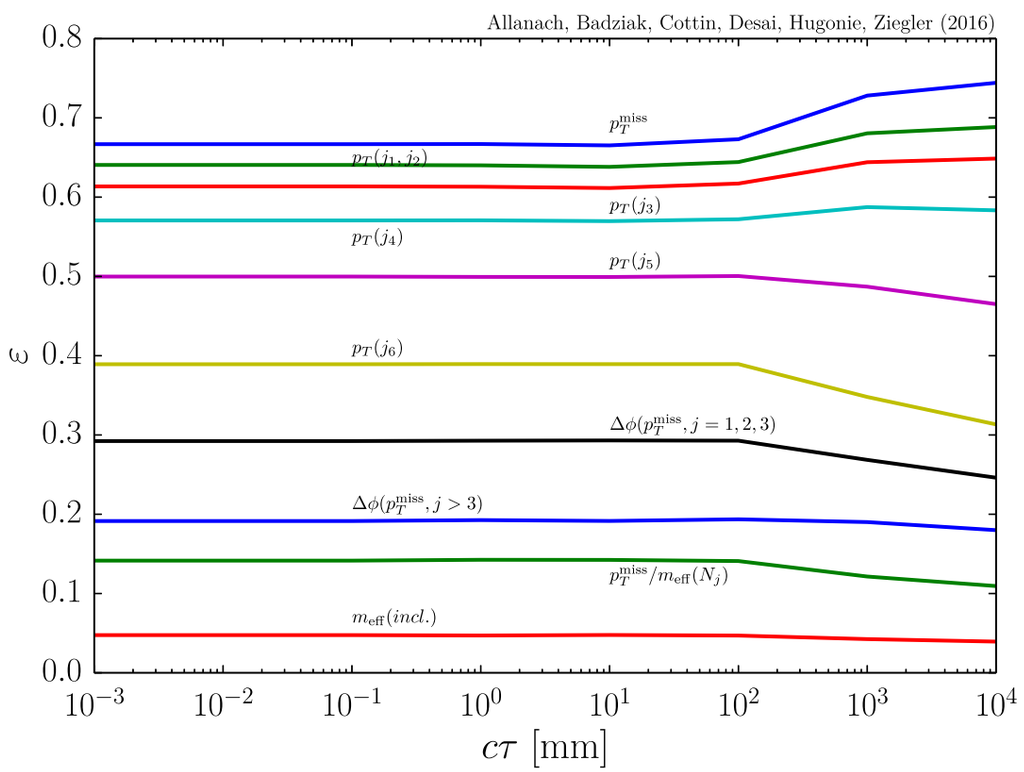
a_1 decays mainly to bb, decay is long lived!

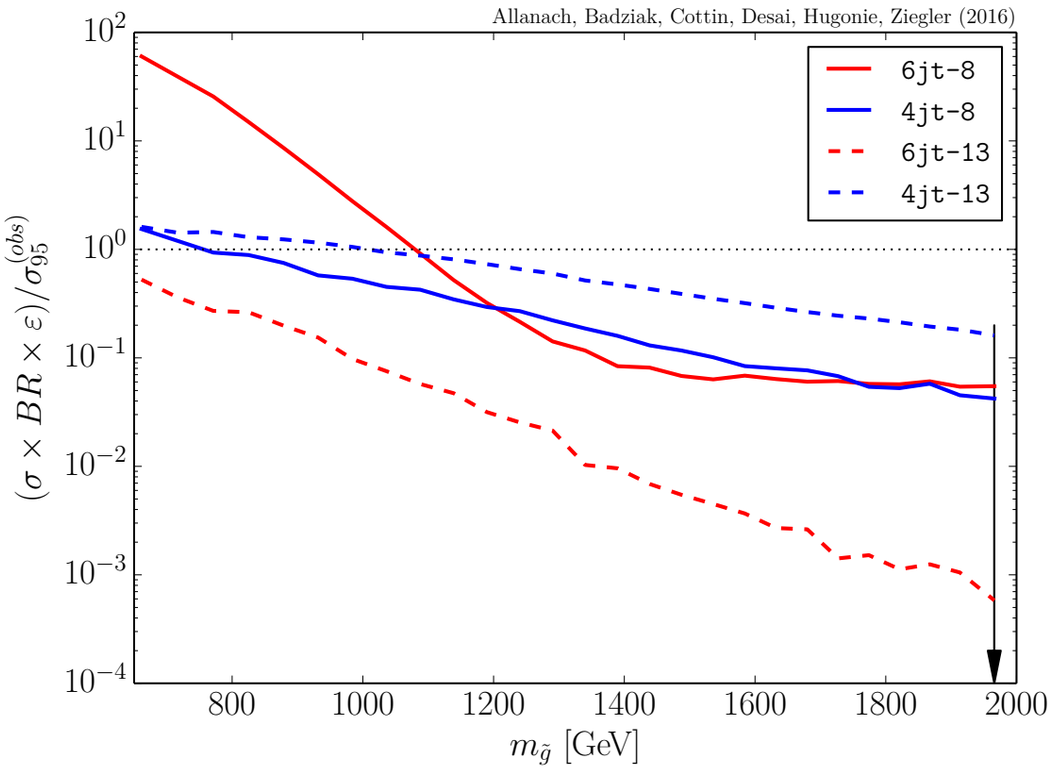
Recasting SUSY jets+MET search

ATLAS coll. EPJC (2016)



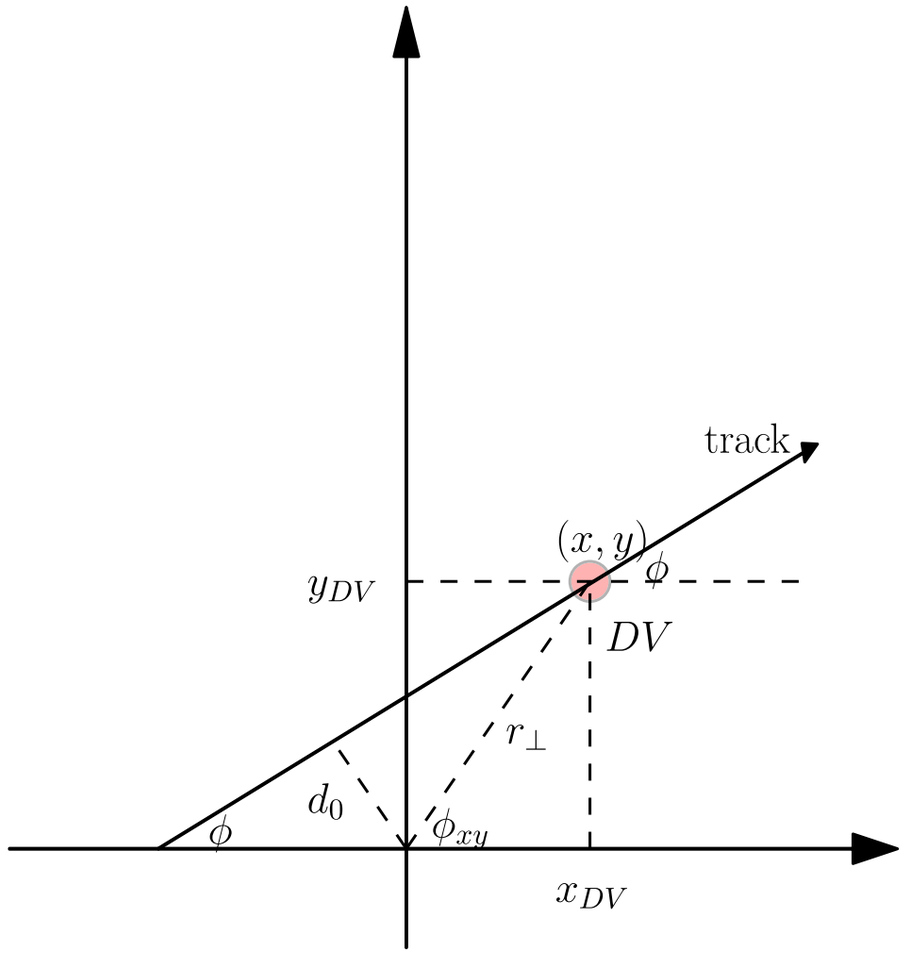
$\sqrt{s}$	8 TeV		13 TeV	
Signal region	4jt-8	6jt-8	4jt-13	6jt-13
p_T^{miss}/GeV >	160	160	200	200
$p_T(j_1)$/GeV >	130	130	200	200
$p_T(j_2)$/GeV >	60	60	100	100
$p_T(j_3)$/GeV >	60	60	100	100
$p_T(j_4)$/GeV >	60	60	100	100
$p_T(j_5)$/GeV >	–	60	–	50
$p_T(j_6)$/GeV >	–	60	–	50
$\Delta\phi(\text{jet}_{1,2,3}, \mathbf{p}_T^{\text{miss}})_{\text{min}}$ >	0.4			
$\Delta\phi(\text{jet}_{j>3}, \mathbf{p}_T^{\text{miss}})_{\text{min}}$ >	0.2			
$p_T^{\text{miss}}/m_{\text{eff}}(N_j)$ >	0.25		0.2	
m_{eff}(incl.)/GeV >	2200	1500	2200	2000
σ_{95}^{obs} (fb)	0.15	0.32	2.7	1.6





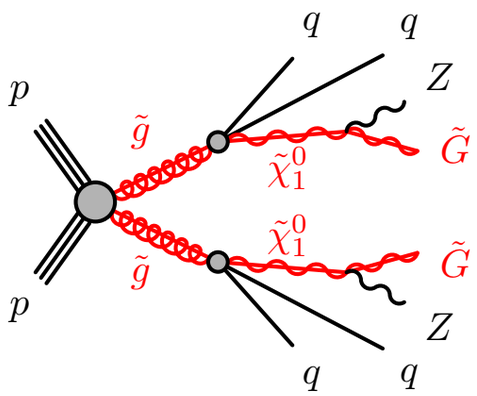
The displaced vertex search

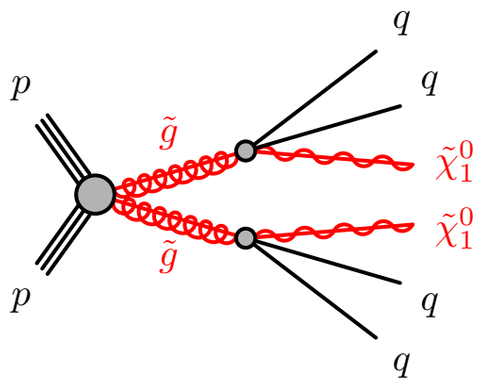
ATLAS Coll. Phys. Rev. D (2015)



DV jets	4 or 5 or 6 jets with $\|\eta\| < 2.8$ and $p_T > 90, 65, 55$ GeV, each
DV reconstruction	DV made from tracks with $p_T > 1$ GeV, $\|\eta\| < 2.5$ and $\|d_0\| > 2$ mm, satisfying a tracking efficiency Vertices within 1 mm are merged
DV fiducial	DV within 4 mm $< r_{\mathrm{DV}} <$ 300 mm and $\|z_{\mathrm{DV}}\| <$ 300 mm
DV material	No DV in regions near beampipe or within pixel layers: Discard tracks with $r_{\mathrm{DV}}/\mathrm{mm} \in$ {[25, 38], [45, 60], [85, 95], [120, 130]}
N_{trk}	DV track multiplicity ≥5
m_{DV}	DV mass >10 GeV

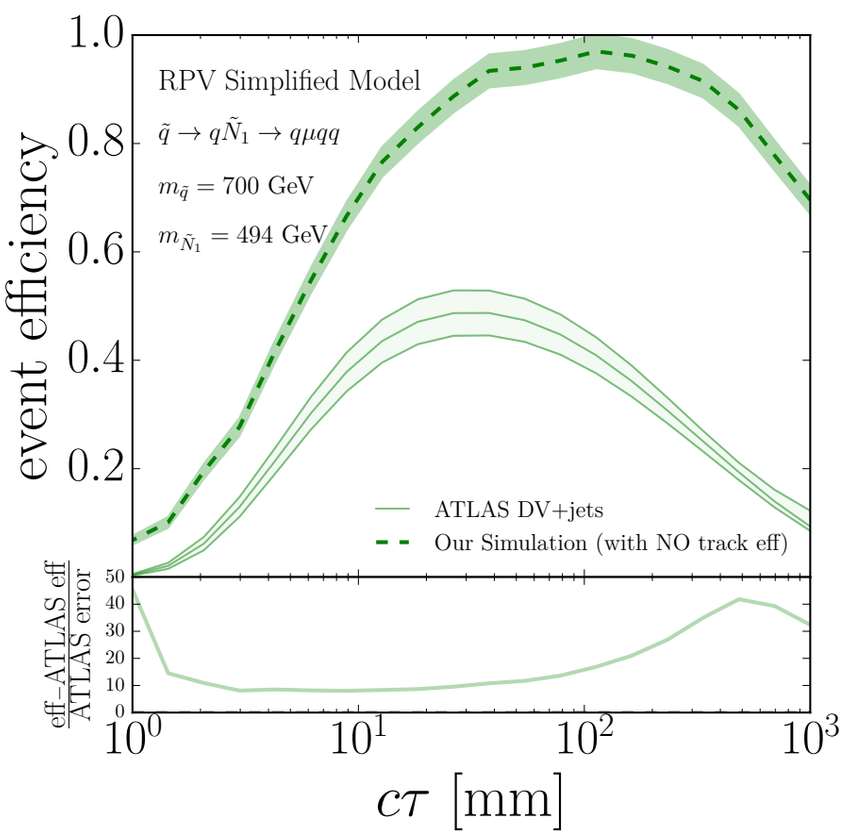
Gauge Mediated benchmarks

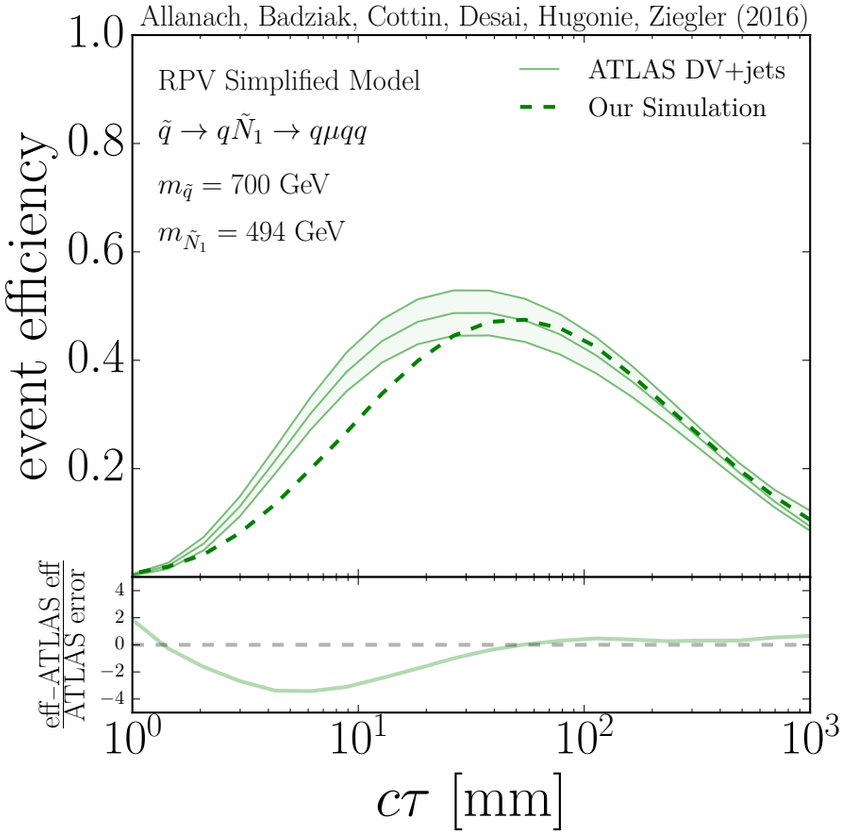




RPV benchmark

Finding the track efficiency





Tracking efficiency determined by fitting parameters of an empirical function

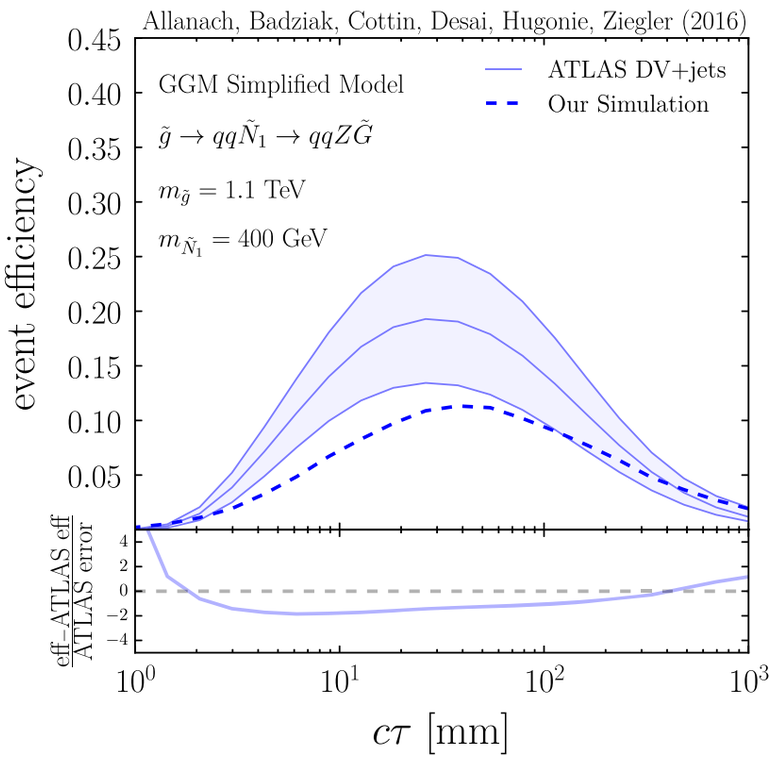
$$\varepsilon_{\text{trk}} = 0.5 \times (1 - \exp(-p_T/[4.0\ \text{GeV}])) \times \exp(-z/[270\ \text{mm}]) \times \max(-0.0022 \times r_\perp/[1\ \text{mm}] + 0.8, 0)$$

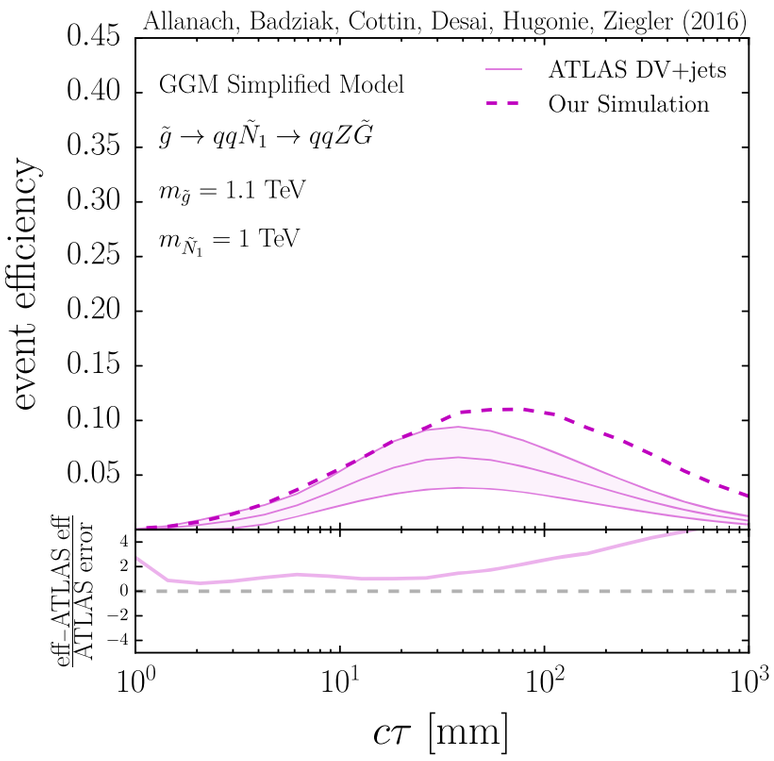
Remove low p_T

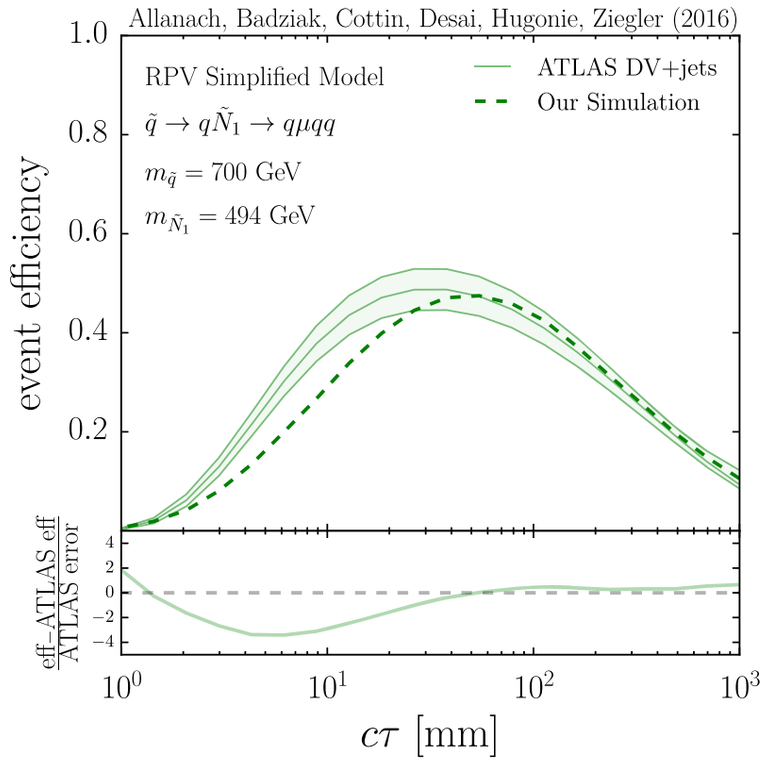
Dependence on z of DV (i.e. truth of decay vertex)

Dependence on radial distance of DV

Finding the track efficiency

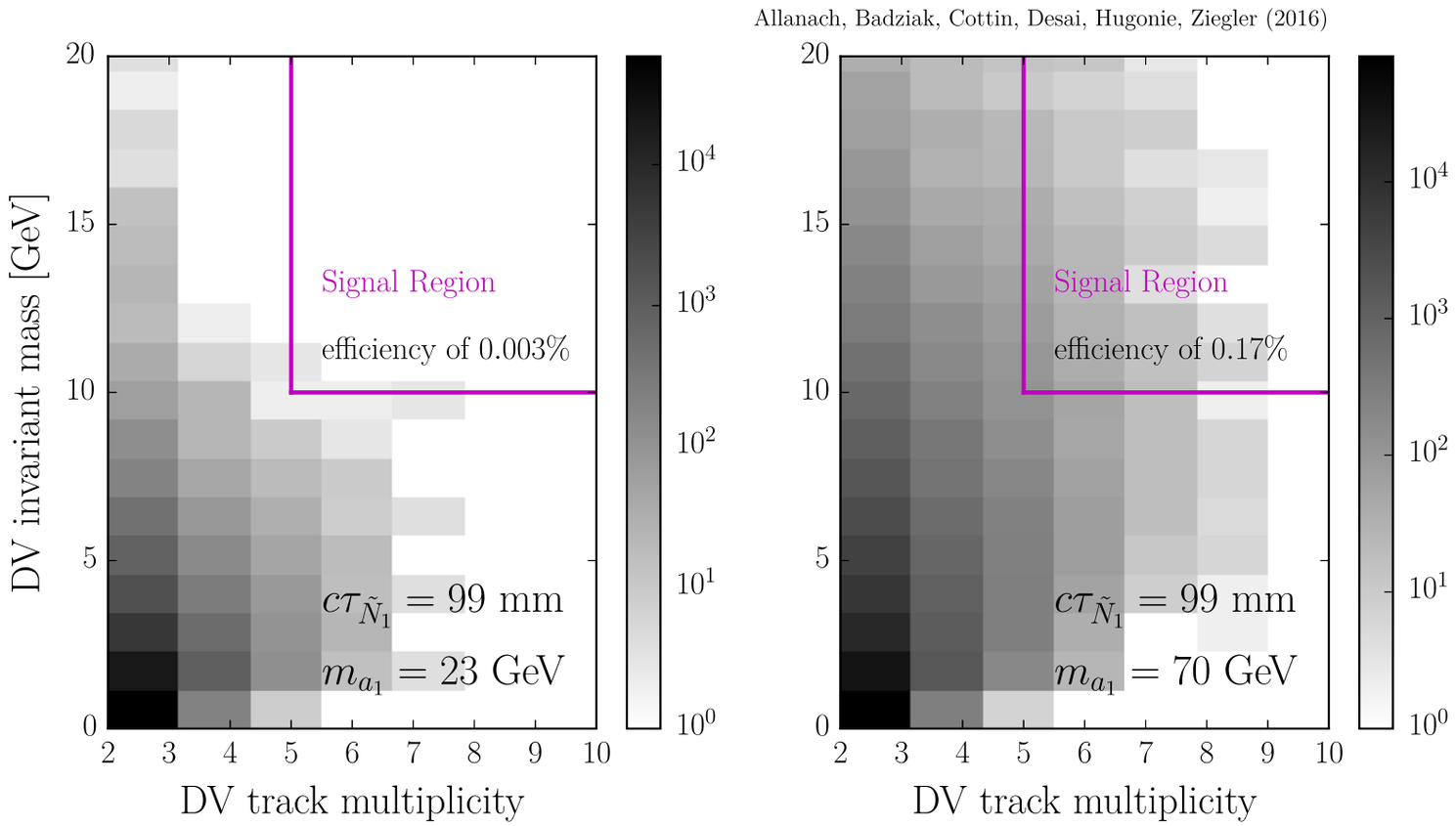






- Fitting any one benchmark gives vary bad fit for others
  - ➡ Not the right parameters? (we tried d_0, z_0 with no improvement)
  - ➡ Hidden dependence on extra variables?
- Three benchmarks used to fit tracking parameters as a compromise

Dependence on DV mass and N_{trk}

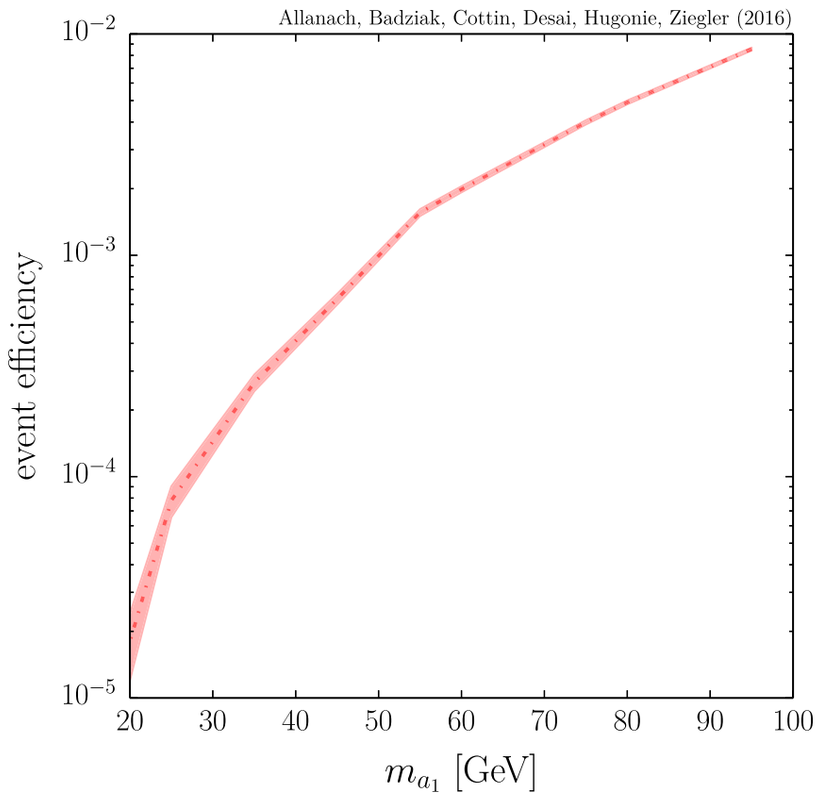


Our model fails to satisfy the DV cuts because of long lived B-mesons in the final state.

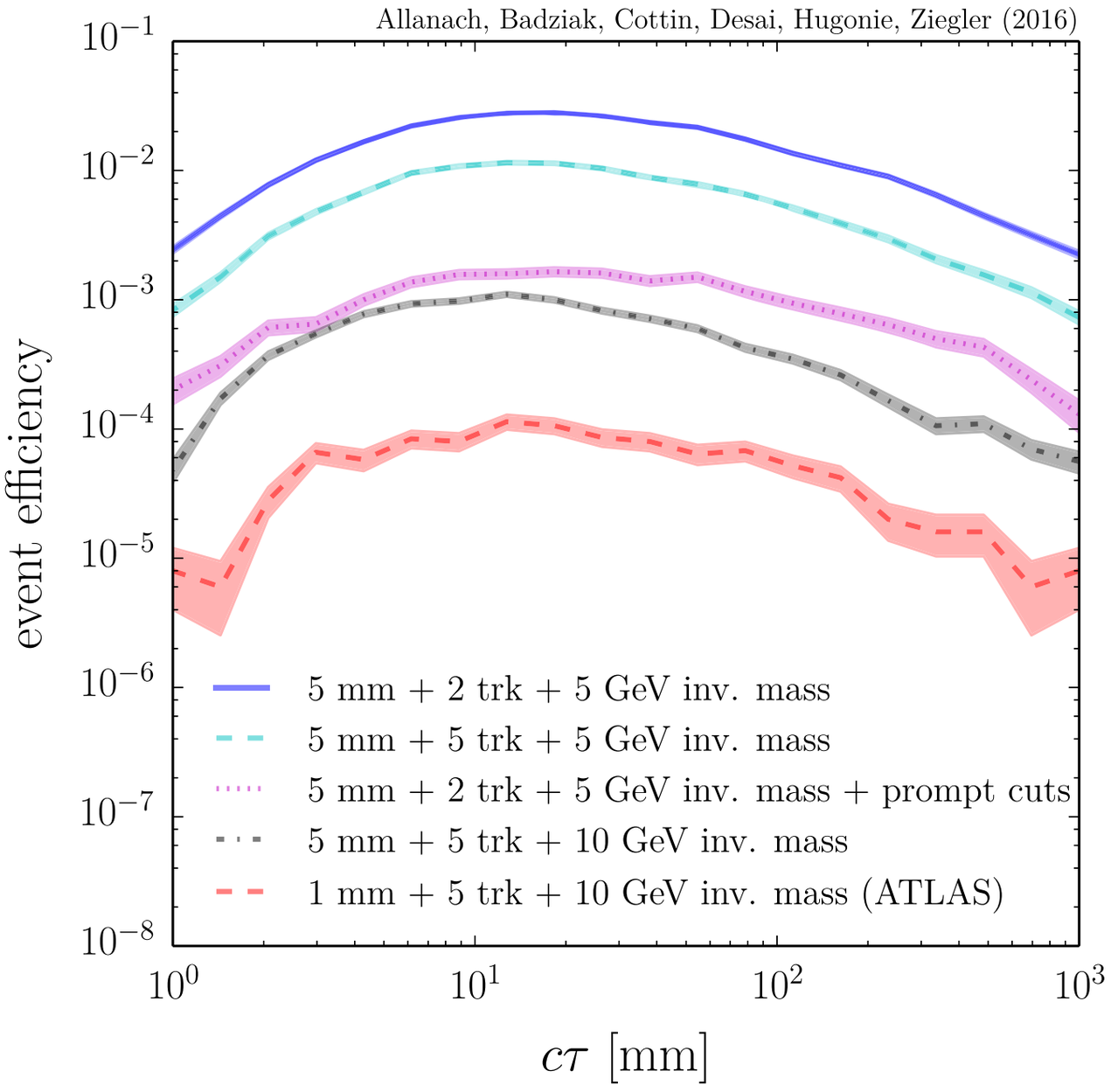
➡ B-mesons themselves give displaced vertices (not enough tracks < 1mm)

➡ Small momentum transfer

This improves with heavier a_1.



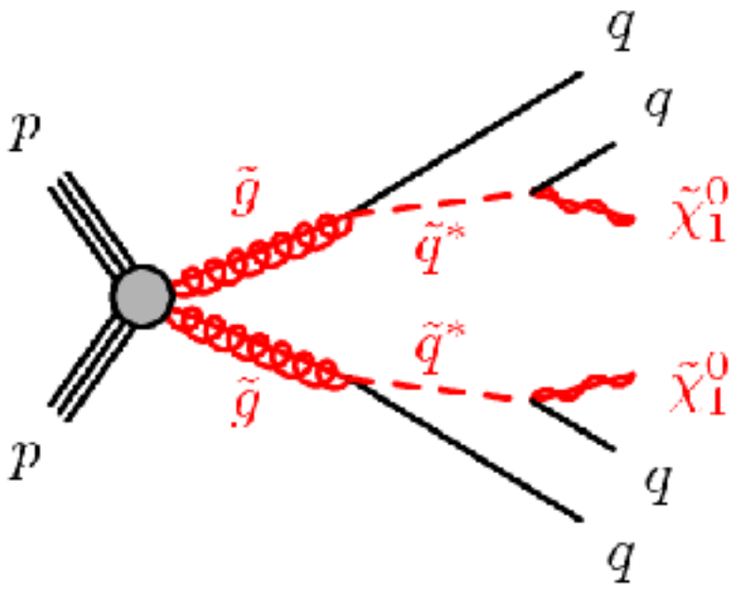
Modifying the displaced vertex criteria

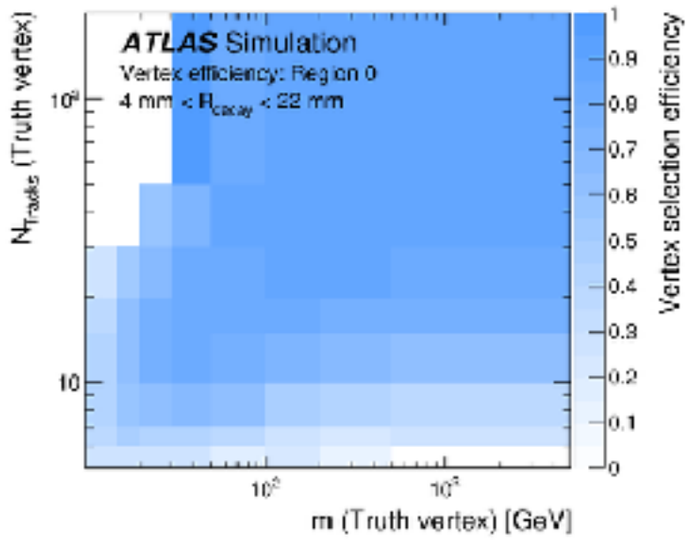


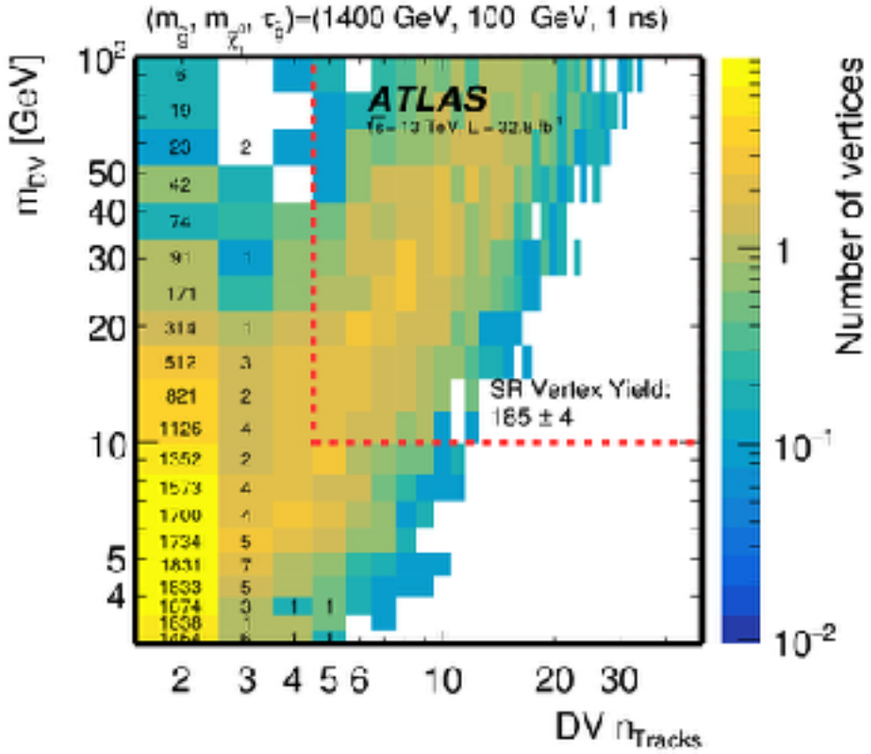
- It is possible to significantly improve efficiency by relaxing cuts
- Not easy to estimate background for these changes
- Our solution: combine prompt cuts + DV cuts & use prompt background estimate as a conservative upper limit
- Reach can be 1.9 TeV with 100/fb (this is better than prompt only!)
- Much better sensitivity possible with better estimate of background

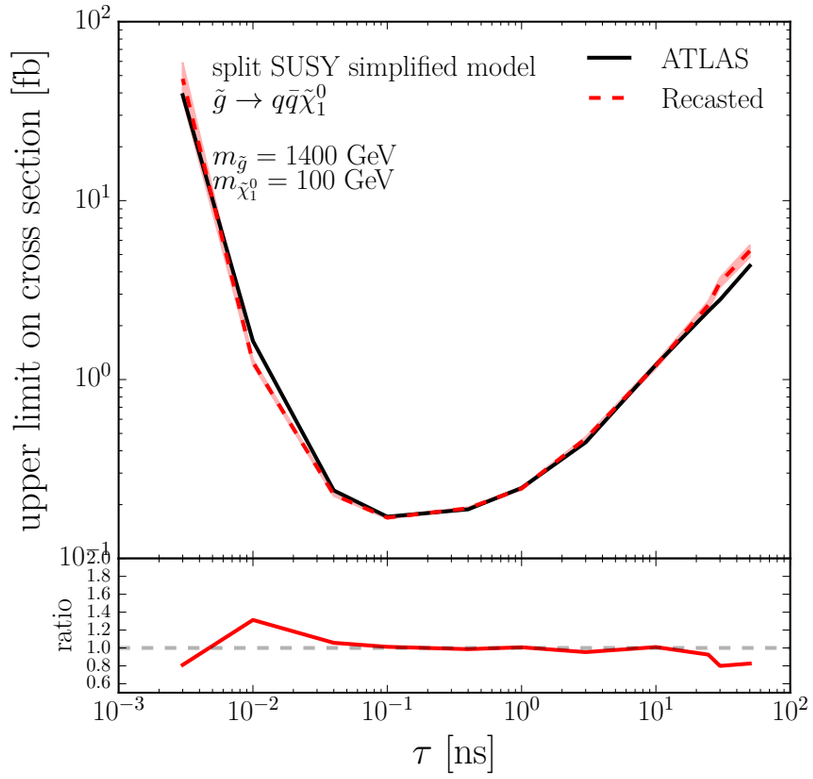
Updated DV analysis

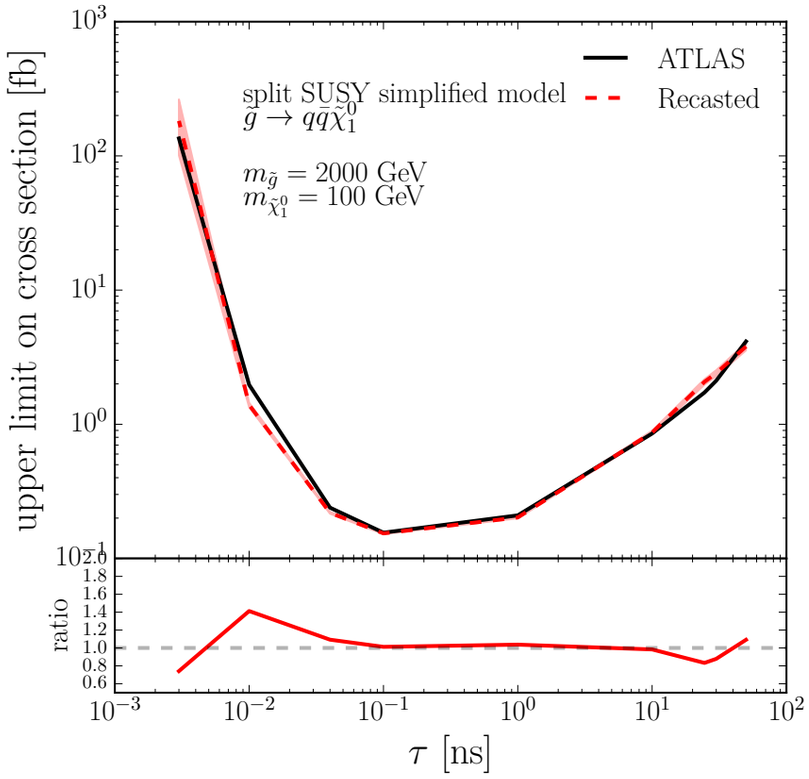
ATLAS, arXiv:1710.04901











Proceedings of 2017 Les Houches workshop; to appear

Summary

- Prompt searches lost sensitivity for this model due to presence of long-lived particles
- Using displaced vertex signature with hard prompt cuts improves sensitivity of analysis + points to underlying model
- Much more optimisation of this search possible with a dedicated background estimate.
- It is currently not easy to recast displaced vertex searches; more input needed from experimentalists
- Also for proposing new searches: how to estimate background for this kind of searches?